SCIENCE

A WEEKLY JOURNAL DEVOTED TO THE ADVANCEMENT OF SCIENCE, PUBLISHING THE OFFICIAL NOTICES AND PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

FRIDAY, SEPTEMBER 6, 1907

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THE NEW OUTLOOK IN CHEMISTRY[1]

Your Excellencies, Your Magnificence, Ladies and Gentlemen:

To-day there has come together here, to welcome a new guest to your noble university, a group of chosen spirits from among the best in this highly cultivated center of learning and civilization. I see before me many men whose names will go down to the future as leaders in their respective widely different fields of work, and rejoice to be in their presence. The opportunity of addressing a gathering so notable could not but be esteemed by anyone as an especial privilege and honor; and to me, whose debt to German scholarship is so exceedingly great, the occasion brings peculiar pleasure.

You are here not only to welcome graciously a newcomer, but also to hear the first lecture of a course concerning one of the most recent developments of human learning. As is well known, the logical process of inductive reasoning based upon carefully planned experiment is relatively a new manifestation of the power of the human intellect. The philosophers of old imagined, observed and reasoned, but neglected experimentation; the artisans, who alone came into close contact with realities, were unable except in the crudest fashion to generalize concerning their results. Because of this separation of thought and deed, man's knowledge of his

[1] Inaugural lecture delivered on May 4, 1907, in the Aula of the Royal Friedrich Wilhelm University of Berlin.

environment remained for thousands of years in a wholly undeveloped state.

From this dormant condition natural science emerged but slowly, although with steadily increasing pace. Little by little, in spite of occasional pauses of inactivity, or apparent forgetfulness, human acquaintance with the fundamental laws of the universe has grown. Each century has added something to the total; and usually each century has added more than any century before. What a contrast such a development presents to that of sculpture, for example, which reached nearly if not quite its highest point of perfection more than two thousand years ago!

In chemistry especially has the acceleration been great; and the effect of recent growth is so remarkable, that, looking back, one is inclined to deny the existence of any real science of chemistry a century and a half ago. If the accumulation of chemical knowledge is depicted diagrammatically in relation to the progress of time, measuring one in the vertical and the other in a horizontal direction, an upward-pointing curve with steadily increasing inclination is obtained. The curve stops at the present day; but unless a cataclysm annihilates the earth's population and its libraries, this line is bound to be continued. Whither will it lead? What further insight into his own constitution as well as that of his environment may man attain? The answer to these questions is fraught with weighty significance as regards the future of the human race.

All the manifold experiences of the human mind are intimately connected with the presence of that which we call material, enlivened by its association with that which we call energy; and the ultimate deciphering of the great mystery of life will depend as much upon the understanding of these as upon the study of the mind itself. Thus modern chemistry should be regarded not only as bringing to medicine and the useful arts its obvious and multifarious contributions, but also as occupying an essentially important place in the realm of intellectual speculation.

First among the influences which have affected the growth of chemistry may be named that kind of insight which may be called the scientific imagination. As this quality of mind has sometimes been assumed to be incompatible with exactness, a brief discussion of its nature will not be out of place. All who have intelligently followed a really original research in chemistry will agree in maintaining that an active and far-seeing imagination is required. Even the gleaner in the field of matter and energy who seeks merely for the facts, without especially concerning himself with the meaning and bearing of these facts, needs imagination, if his work is to be useful. He who lacks imagination will see only that which he is told to see. In any but the simplest scientific task, the mind of the investigator must conceive of many underlying conditions and possible modifying circumstances which are not apparent at first sight, and which demand imagination for their detection and proper adjustment. The highest type of scientific man—he who compares and generalizes his facts, who frames hypotheses concerning their ultimate nature, and who from these tentative speculations evolves new experiments to expand his knowledge—needs an imaginative mind in a yet higher degree. Dealing with impersonal things, instead of with personal emotions, this imagination is indeed of a somewhat different type from that exercised by the poet or artist; but it is none the less fitly to be considered as true imagination, and it likewise yields the singular delight of creative power to its possessor.

Not always have the two types of imagination, the scientific and the poetic, been separated in individuals. Indeed the occurrence of the two in the same individual is so often to be noticed that the two types might well be supposed to be really the same in essence and to differ only in their field of development. History furnishes many a proof of this twofold exercise of originality. For example, Leonardo da Vinci furnishes striking evidence of the manifold working of a powerful imagination. Leonardo was no less eminent as a geologist and engineer than as an artist and a poet. Chemistry too was profoundly interesting to him. His extraordinary writings manifest the fruitfulness of an imagination which has rarely been equaled. His few paintings, which show surpassing insight into human nature and unusual technical skill, were the expression of the same imaginative force. If Leonardo were living to-day, he might be as well known for his investigations into pure and applied science as for his artistic preeminence, since these fields of thought now have much more to offer to the imaginative mind than they had in the days when their scope was more restricted and less appreciated.

In more recent times, Goethe furnishes one of the most brilliant examples of a truly poetic mind which found joy in scientific studies. Goethe was not only one of the greatest poets of all times; he made also notable contributions to the science of his day. The imaginative quality which gives the pervading charm to one product of his genius gave insight to the other.

These are examples of men primarily known for their ability in the directions commonly recognized as imaginative, who have possessed also ability which was or might have been developed in a scientific direction. One may find likewise many cases of the dual use of the imagination among those who are known chiefly for their scientific productions. For example, von Helmholtz's interest in sound was not purely mathematical in its expression; the great physicist loved music for itself, having a wide knowledge of its literature and keen pleasure in its performance. Robert Wilhelm Bunsen's delight in the beauty of the Italian landscape, especially of the country around Naples, will be remembered by any one who knew him; this poetic appreciation, artistic in feeling if not in expression, persisted even to his old age, after pain and disability had caused his interest in chemistry to wane.

The case of Charles Darwin, which is the one example usually cited to prove the supposed incompatibility of the scientific and poetic imaginations, is perhaps rather to be referred to another category. One can hardly follow his long combat with ill-health without feeling that this misfortune, not his scientific interest, was the cause of the apparent atrophy of his literary and artistic sympathy. Darwin in his youth was extremely sensitive to every imaginative impulse; and years of suffering were needed to deaden this intense sensibility.

There is no need of multiplying the many possible examples of this kind, however, for the best place to find evidences of the imaginative insight of a scientific man is in his own work. Here, where his mind has dwelt longest, his mental vision will find its widest scope. Perhaps the most easily traceable record of this immediate effect of the scientific imagination is to be found in the life of Faraday, because he committed his wildest dreams to the pages of existing notebooks. Faraday's originality ranged at large over the whole field of chemistry and physics; to him nothing seemed too strange to be possible, no relation too unlikely to be unworthy of thought. But with this extraordinary disposition to

dream things before undreamt, he possessed the steadying power of judgment which enabled him to dissociate his dreams from the reality. He always sought to test each hypothesis by actual experiment, and cheerfully recorded every overthrow when he was convinced of its finality. Experiment served to keep him scientifically sane, and day-dreams inspired his enthusiastic nature to undertake further experiment. Thus each helped the other, with a rare cumulative effect. Without imagination, Faraday could not have made most of his discoveries; but without profound common sense, he would have ended in a madhouse.

The example of Faraday serves also to emphasize the indisputable fact that imagination alone is not a sufficient intellectual outfit for the scientific man. At least one other attribute is essential, namely, good judgment, or common sense, to select between the various possible interpretations of fact and theory presented by the imagination. So emphatically is this true that Huxley maintained science to be nothing more than systematized common sense.

Imagination, then, and good judgment, are necessary, if science is to grow. But both of these admirable qualities were possessed in large measure by some of the ancient philosophers, who nevertheless made but little real progress. What was lacking, that so little advance should have been made in the 400 years between Democritus and Lucretius, and so little more in the succeeding centuries?

To-day, in the light furnished by any successful scientific investigation, the answer, given a few minutes ago, is manifest. This answer is so important that its substance may be repeated. The philosophers with all their intellectual greatness and insight, were too far removed from realities. More thorough observation, more consistent study of the actual operation of the law of cause and effect, and above all more frequent reference of each doubtful case to the almost neglected test of actual experiment should have supported their too vague speculations.

Accurate observation and well-planned experiment, then, besides imagination and good judgment, are needed if science is to advance. But long ago all these essentials were at the command of a few of the best of the alchemists, and yet chemical science loitered in its ever-onward way.

Chemistry began really to become a science and to enter upon the phenomenal growth of recent years only a little over a century ago. Since then its development has been one of the most remarkable features of human progress, and its results are among the most important of human intellectual possessions.

What was the reason for this striking transformation? What was the key with which modern chemistry has opened the door to her treasure house? The answer is easily found. Measurement, the accurate evaluation of the numerical relations of things, has been the "open sesame" whose magic influence has slowly disclosed the hidden wealth. As van't Hoff has pointed out, each new instrument for measuring a given phenomenon of nature led immediately to a greatly accelerated development in that particular field.

No wholly new idea exists under the sun, it is said. Certainly the perception in general of the importance of measurement is almost as old as the hills, although its effect upon chemistry was so long postponed. Plato over two thousand years ago put into the mouth of Socrates the equivalent of these words: "When measuring and weighing and the idea of number are taken away from an art, how little of that art is left!" Essentially this conviction led

Kant to exclude chemistry from the list of true sciences. In Kant's day, as he rightly maintained, chemical inferences depended so little upon any data capable of mathematical treatment, that the experimenter was liable to fall into extraordinary errors of interpretation. The world-wide prevalence of the oddly inverted theory of phlogiston, which imagined that a metal in rusting lost something of its substance is evidence of this defect. Such a theory became untenable as soon as measuring, weighing and the idea of number removed the cause of Kant's reproach.

Measurement, then, revolutionized chemistry—but what forms of measurement? History tells no equivocal tale on this score; every form of measurement whose careful application has laid the foundations of the present science of chemistry is quickly seen to belong to the domain of physics. This is not surprising, since only two of the traditional five human senses, namely, taste and smell, are purely chemical in their action; and these are not easily amenable to precise quantitative treatment. All the other senses, sight, hearing and touch, through which man obtains knowledge of the outside world, depend upon the interposition of physical energy; and the methods of measuring must correspond to this fact.

Thus, Joseph Black brought the balance, an essentially physical instrument, into requisition in order to demonstrate the nature of the caustic alkalies. Lavoisier used the balance to prove the fundamental laws of conservation of mass. The same instrument alone afforded Dalton a sound basis for his laws of combining proportions and of multiple proportions, and therefore the first unimpeachable argument in favor of the ancient atomic theory in which he had believed from childhood. The study of the densities of vapors, of the specific heats of solids, and of the forms of crystals, all found by processes of physical measurements, were the foundations upon which by degrees a logical system of chemical notation was built. The discovery of the quantity-dimension of electrical energy led in Faraday's hands to the new definition of chemical equivalents. The spectroscope, a physical instrument, in the hands of Bunsen and Kirchhoff made possible the detection of new chemical elements. Physical measurements of osmotic pressure led van't Hoff to a new conception of the phenomena of chemical relations in solution; and electrical conductivity was used by Arrhenius as the basis of the generally accepted theory concerning a large majority of the ordinary reactions between inorganic substances. Both the free energy change and the total energy change of a system undergoing a chemical reaction are measured by physical methods, and the proof of Nernst's equation depicting the mechanism of the galvanic cell depends upon the precise evaluation of small electromotive forces. Again, Lord Rayleigh's exact quantitative determinations of the densities of gases with Ramsay's help led to the discovery of a whole series of new elements possessing extraordinary properties. Still more recently physical methods of research are used in identifying the yet more extraordinary radioactive substances, and in endeavoring to solve the unanswered riddle of their possibly transitory existence. Finally, exact analysis, based upon weighing, alone made possible the exceedingly complex syntheses of organic compounds carried on by a long line of brilliant chemists culminating in Emil Fischer. These are only a few striking instances of the discoveries in chemistry which are essentially dependent upon physical processes.

Thus if the various methods of measure-

ment borrowed from physics were taken away from the chemistry of to-day, but little would be left of the science. Chemistry would then become a purely qualitative observational study; she could penetrate but superficially into the hidden world. Therefore it would not be an extreme statement to call all quantitative chemistry *physical* chemistry, with the understanding that by physical chemistry in this sense is meant the application of physical methods of research to the study of chemical problems.

Indiscriminate measurement will lead nowhere, however. The results of the numerical determination of chemical phenomena are by no means all of equal importance. They may be divided into two classes: the first class comprises those which are variable and accidental, depending upon the relatively unimportant conditions of the special case, such as the analytical composition of a piece of granite; and the second class comprises those which are invariable and general, recurring almost or quite unchanged under widely varying conditions. Such results as the latter may be called "physicochemical constants." They claim our immediate attention.

A "physicochemical constant" is a numerical magnitude expressing one of the numerous apparently permanent quantitative relations of mass or energy which seem to be essentially associated with the elementary substances, or chemical elements, and their compounds; it is a fundamental fact, a unique number which touches very closely the ultimate structure of material. As examples, the atomic weights stand out strikingly. Whether or not these quantities, representing the relative weights in which elementary substances combine with one another, are to be referred to the weights of hypothetical atoms, they are certainly concerned in determining the composition of every compound substance in the heavens above, on the earth beneath, or in the waters under the earth. Every proteid in each muscle of our body, every drop of liquid in the ocean, every stone on the mountain top bears within itself the stamp of the influence of this profoundly significant and impressive series of fourscore numbers.

The heat evolved during any chemical combination typifies a different kind of physicochemical constant. Coal on burning sets free a quantity of heat which mankind uses in exceedingly divers ways, deriving therefrom the major part of the energy of manufactures and transportation as well as that needed to warm his habitations. The evolution of quantities of heat in this and other chemical reactions indicates a decrease in the total energy of the substances during the reaction involved; therefore from the point of view of the chemical philosopher, as well as from that of the practical engineer, these figures also are of great importance.

Many other examples of other types of constants might be cited, such as densities, compressibilities, or electrochemical equivalents; all are not of equal significance, but each in its way is fundamental. These properties although undoubtedly somewhat connected with one another, can not yet be safely predicted; each must be ascertained for itself. Thus a colossal task is involved in their accurate determination.

How nearly has this task been completed? The comparative study of the existing accumulation of experimental data concerning chemical phenomena affords reason for congratulation that so much has been done within a single century; but it also reveals the fact that much remains to be done. For in spite of the fact that physical measurements are the basis of all

quantitative chemistry, we find, upon comparing the probable accuracy of most results in chemistry with the probable accuracy of many results in physics and astronomy, that chemistry is at present far in the background. In physics or astronomy results attaining an accuracy of one part in a hundred thousand are by no means uncommon, and often a much higher degree of precision than this is reached. For example, in weighing it is easy to detect one tenth of a milligram in a kilogram, a fractional part of only one in ten million. Again, the length of the year in terms of the length of the mean solar day is probably known to within one part in a hundred million. On the other hand, in chemistry few results are to be relied upon to within one part in 500, and many investigations, even of the atomic weights, have yielded results which are not to be trusted within one per cent. Such an error is 100,000 times as great as the possible error of the process of weighing alone.

Why is chemistry still so much behind physics and astronomy in quantitative consistency, when all three sciences depend upon the same methods of measurement? Are the supposed constant magnitudes to be measured in chemistry really variable, that their range of uncertainty should be so large? If they are thus variable, is it worth while to expend much labor in determining the values which they happen to possess at any one time under any one set of conditions?

The question as to whether or not the supposed constants of physical chemistry are really not constants, but are variable within small limits, is of profound interest and of vital importance to the science of chemistry and to natural philosophy in general. If this latter alternative is true, the circumstances accompanying each possible variation must be determined with the utmost precision in order to detect the ultimate reason for its existence. As Democritus said long ago, "the word chance is only an expression of human ignorance." No student of natural science who perceives the dominance of law in the physical universe would be willing to believe that such variation in a fundamental number could be purely accidental. Every variation must have a cause, and that cause must be one of profound effect throughout the physical universe. Thus the idea that the supposed constants may possibly be variable instead of invariable, adds to the interest which one may reasonably take in their accurate determination, and enlarges the possible field of investigation instead of contracting it.

Possible variability is by no means the only reason for being interested in the more accurate determination of the physico-chemical contents, however. Many considerations show that whether the constants are changeable or not, more time and care may be profitably spent upon them than has been spent in the past. The argument may be epitomized by referring back to the theorem of Plato, and somewhat extending it. Plato said: when measuring and weighing and mathematics are taken from an art, there is little left of that art. May we not add that the more efficiently weighing and measuring are used in any art, the more valuable that art becomes? If, as Kant has it, a subject becomes truly scientific only when its facts are susceptible of mathematical treatment, then an extrapolation enables us to say that a subject becomes the more scientific the more accurately the mathematical premises are ascertained. Huxley was wont to say that mathematics might be compared to a mill which would grind exceedingly fine all that was placed within it, but was incapable of making wheat

flour out of porscods. Interpreting the simile to suit the present case, it may be said that the accuracy of a quantitative conclusion must depend upon the accuracy of the data upon which it is based.

For example: it has long been surmised, because of the undoubted periodic relations of the elements, that the atomic weights have some fundamental numerical connection with each other. Many acute thinkers have attempted to discover such relations, and some regularities have indeed been found. Obviously, however, if the data are sometimes as much in error as a whole per cent., nothing but vague conclusions can be drawn from such numerical speculations; the time spent upon them is little better than wasted. Before the real numerical relations between the atomic weights can be discovered, it is safe to say that the magnitudes of many of them must be known far more exactly than this. Thus for such speculations the precise determination of these physicochemical constants is essential.

But this case is only an example of a series of similar cases. In general, it is not an exaggeration to say that in order to obtain the ultimate understanding of the mysteries with which chemistry is concerned, all the fundamental data must be determined as accurately as possible. From the point of view of the chemical philosopher no pains is too great for determining these data upon which all his really scientific conclusions must rest.

Thus it is clear that exact experimentation, instead of being as some of the earlier philosophers supposed incompatible with imaginative impulse and unworthy of a true thinker, furnishes the only basis upon which the imagination has a right to build. No hypothesis which disregards the results of measurement is worthy of a moment's consideration; but given these results, fancy may exercise itself at will within the limits thus imposed. The restriction is salutary, because speculation basing itself upon reality is much more likely to reach a useful hypothesis than when unrestricted; and there is plenty of room left for fancy. The quantitative results direct, but do not really hamper imagination.

These lectures will discuss the theory and practise of exact physicochemical measurement. It will be shown that much of the uncertainty affecting the present data of physical chemistry is due neither to the variability of the fundamental phenomena themselves nor to the inability of the physical methods of measurement to yield constant results, but rather to the superposition of other inessential phenomena upon the fundamental ones which it is desired to measure. The discovery and elimination of these inessential phenomena, chiefly chemical in their nature, are really the difficult parts of the measurement; it is their successful accomplishment which makes all the difference between success and failure, and offers a task demanding the ablest knowledge and insight, both chemical and physical, theoretical and experimental. Whether perfect constancy will have been reached when all inessential phenomena have been eliminated, no one can certainly say.

But after all, one may ask, is it worth while in a world filled with burning practical problems demanding speedy solution to expend so much valuable time and energy merely in adding another certain decimal place to a collection of rather dry figures for the sake of abstract scientific learning?

When answering such a challenge, in a manner convincing to the practical man, one must recall to mind again the fact that chemistry serves the world in a twofold

fashion, partly as an essential factor in our mechanism for directly obtaining and preparing most of the material comforts of modern living, and partly as one of the most intimately searching of the available rays of intellectual light on the philosophy of nature. The usefulness of the science in its former capacity is easily traced, and any one can see that as methods of manufacture are improved and competition increases, the numerical data involved must be more accurately known. Nevertheless, this manner of helping mankind, although the most direct and obvious, is by no means the most effective way in which increased precision in scientific work may be of service. A much greater gain is ultimately made, although indirectly, through the vastly augmented clearness of view which is given to the science as a whole by the increased stability and trustworthiness of the fundamental basis of facts. The resulting growth of either physical or chemical science as a whole not only brings with it increased satisfaction, and respect for man's intellect; it may also at any time lead to wholly unexpected and unforeseen developments of practical usefulness about which man could not otherwise have dreamed. Thus Liebig and Soubeiran, when they found chloroform, little thought of the priceless boon which the new substance would bring with it to suffering humanity. Faraday, in studying the behavior of wires and magnets, never dreamed of the miracles to be wrought by the modern dynamo. Röntgen was striving only to advance scientific knowledge and not to furnish a sure guide to the puzzled surgeon in his crucial task, when the almost incredibly penetrating rays were discovered.

These records of the past lead us to look forward towards the beckoning future. Has the advantage to humanity to be gained by furthering pure science come to an end? No, a hundred times no! Not until man really understands himself and his environment, will the possibility of the discovery of some new blessing be ended. Prophecy is inevitably uncertain; and yet when one realizes that our frail and often jangling human mechanism is actuated essentially by a series of chemical reactions, and that every material thing connected with our life is a chemical substance, one feels that chemistry must still have vast treasures in store for the human race. What may she not accomplish for the comfort of living, for a rational practise of medicine, for a profound philosophy of nature! One can not but believe that as yet her mission is scarcely begun; and if this mission is to be fulfilled, the great result must be wrought not by superficial, but by fundamental understanding, built upon the solid foundation of exact knowledge.

THEODORE W. RICHARDS

SCIENTIFIC BOOKS

The Warblers of North America. By FRANK M. CHAPMAN, with the cooperation of other ornithologists. With 24 full-page colored plates, illustrating every species, from drawings by LOUIS AGASSIZ FUERTES and BRUCE HORSFALL, and half-tones of nests and eggs. New York, D. Appleton & Company. 1907. Pp. x + 306. Cloth, $3.00.

Few groups of North American birds are of such general interest as the wood warblers, and this attempt to bring together the information concerning them is a welcome addition to ornithological literature. Its title, however, would much better have been "The Wood Warblers of North America," for the true warblers, family Sylviidæ, also represented in North America, are not treated at all.

Following an "Introductory" chapter, in which the plan of the work is outlined and a

list of contributors given, comes the first division of the subject, a consideration of "The Wood Warblers" in general. In this division are the eight headings: General Characters, Plumage, Distribution, Migration, Songs, Nesting Habits, Food, and Mortality. Of these the article on "Migration of Warblers," by Professor W. W. Cooke, that on "Food of Warblers," by Mr. Edward H. Forbush, and that on "Mortality among Warblers," are particularly interesting.

The second division, which comprises the major part of the book, is concerned with a detailed treatment of genera, species and subspecies, unfortunately following the inverted order of Mr. Ridgway's recent review of the family, without his excellent reason therefor. This portion includes for each genus its diagnosis and general characteristics; and for each species and subspecies pertinent information condensed into readily accessible form under a number of subheadings. "Distinguishing Characters" consist of the salient differential points of plumage, together with usually the measurements of total length in skin, wing, tail and bill. We are not, however, altogether satisfied that, as Mr. Chapman claims, the total length of a bird can be more accurately ascertained from a dried skin than from a fresh specimen! Descriptions of the various phases of plumage, from nestling to adult, are next given, and these seem to be full enough for most purposes of identification and comparison. "Geographical Distribution," written chiefly by Professor W. W. Cooke, follows, and is in most cases excellent and very complete, being separated under General Distribution, Summer Range, Winter Range, Spring Migration and Fall Migration—an admirable arrangement, although the General Distribution would much more logically have included the winter as well as the summer home. "The Bird and its Haunts" includes various notes on general habits—again much information in a small compass. Other captions, self-explanatory, are "Song," "Nesting Site," "Nest," "Eggs," "Nesting Dates" and "Biographical References" (to literature).

A "Hypothetical List" of two pages enumerates the species that, according to our author, have but a questionable place in the North American list, by reason of doubtful specific validity or unproved occurrence within our limits.

The book is illustrated by 24 colored plates of birds, 4 half-tones of nests and nesting sites and 4 of eggs. The half-tones, as well as the colored figures, with a few exceptions, such as the water-thrushes, ovenbird and cerulean warbler, are good.

HARRY C. OBERHOLSER

Étude minéralogique des produits silicatés de l'éruption du Vésuve (Avril, 1906). By A. LACROIX. Paris, Nouvelles Archives du Muséum, (4). Vol. IX. Pp. 1–172, 1907.

In this valuable and important work the foremost petrographer of France brings together many observations made by himself at eruptions of Vesuvius in 1893, 1905 and 1906, with results of great interest both for the study of volcanic eruptions from the physical side and of the petrography of their products.

In the first chapter a general sketch of the Vesuvian eruptions is given, followed by a detailed description of that of 1906. Two main types of eruption (both central) are distinguished: that of 1895, in which the effusion of lava is tranquil and extends over several months and that of 1872, in which it is violent and rapid, and lasts only a few days. The eruptions of the first type are constructive, so far as the cone is concerned, while those of the latter are destructive. A third, subsidiary type, rare at Vesuvius while the usual one at Etna, is that of 1760, characterized by excentric outflows, the other features being intermediate between those of the first two. The eruption of 1906 belongs to the type of 1872, ending a period of moderate activity which had lasted for nearly 32 years.

In the second chapter the new lavas are described petrographically in considerable detail, two chemical analyses being given, which resemble closely earlier ones of lavas of 1631, 1872 and 1903 made by the reviewer. The leucite phenocrysts appear to have formed

prior to the effusion, but at moderate depths; while the formation of the microlites of leucite took place during the effusion. The lapilli which covered Ottajano show very decided chemical differences from these, especially in their higher magnesia and lime and lower alkalies.

In Chapter III. are described the fragments of an earlier date brought up by the last eruption, including lavas, tuffs, intrusive rocks and metamorphosed limestones. In Chapter IV. the effects of autopneumatolysis and metamorphism on these fragments at Vesuvius, and in Chapter V. the similar phenomena at the volcanoes of the Auvergne, Santorini and Martinique are discussed. Many interesting details are here given, which are too numerous for review and for which the original monograph must be consulted.

The final Chapter VI. is devoted to a general discussion and description of the eruptive rocks of Somma and Vesuvius, and is to the petrographer the one of greatest interest and value. A large number of diverse types are described, accompanied by numerous, good analyses by Pisani. Lacroix shows that the variation in composition, both mineralogical and chemical, of the Vesuvian lavas is far greater than has hitherto been thought. In the terms of the prevalent classifications the rocks described are leucite-phonolite, leucite-tephrite, trachyte, phonolite, sanidinite, microsyenite, sommaite (leucite-monzonite) and monzonite, with corresponding chemical differences, the silica, for instance, varying from 47.31 to 58.61 per cent. In terms of the quantitative classification, which, it is of interest to observe, is employed throughout the work in connection with that commonly in use, the subrangs represented are beemerose, procenose (I. 6. 2. 3), miaskose, ciminose, shoshonose, borolanose, braccianose, vesuvose, shonkinose, ottajanose (III. 6. 3. 2), ourose, and an unnamed one (III. 8. 2. 3). It may be noted, however, that, while the mineralogical and chemical complexity of the mass is thus evident, yet that the predominant rocks are leucite-tephrites, belonging to the subrangs borolanose and braccianose of the quantitative classification, the non-leucitic rocks and those belonging to the persalane and salfemane classes being present in comparatively small amounts. From the analytical data presented Lacroix considers that the average magma of Somma-Vesuvius belongs to borolanose (II. 6. 2. 3), the Vesuvian lavas being mostly dopotassic, while the lavas and tuffs of Somma are for the most part sodipotassic. This introduction of the materials of Somma into the calculation explains the divergence from the position of braccianose (II. 7. 2. 2) previously assigned by the reviewer to the Vesuvian magma. In this final chapter is also included a brief discussion of the formation of leucite, the author laying special stress on the physical conditions, while the reviewer has recently (in the *Journal of Geology*) discussed the question chiefly from the chemical side, the results of both being in harmony with each other.

Ten plates of excellent phototypes, illustrating, the microscopic and megascopic modes and textures of the rocks, close the volume, which is a most important contribution to our knowledge of Italian volcanoes, and is an illuminating example of a modern petrographic monograph.

HENRY S. WASHINGTON

The Royal Society: some account of the "Classified Papers" in the Archives; with an Index of Authors. Compiled by A. H. CHURCH, D.Sc., F.R.S. Oxford; printed for the author. 1907. Pp. 38. Royal 8vo.

Professor A. H. Church, the distinguished chemist, student of colors, water, gems, and critical author, has published a most exhaustive and interesting account of the "Classified Papers" in the archives of the Royal Society of England. These papers are collected in thirty-nine guard-books, which were made up in 1740 or 1741; a few of the papers were printed, but the greater part are in manuscript. Professor Church gives a comprehensive, clear and incisive account of the formation and character of the early history of that learned institution, known for the past two and a half centuries as "The Royal

Society," in a stately octavo, printed from an unusually neat and clear type. While the first charter of the society was granted July 15, 1662, some of these papers are of earlier date and a few even belong to the time of King James I. It appears that there was a committee of trades connected with Philosophical Society or Assembly, out of which the Royal Society was developed, and some of the more practical papers were contributed to this committee. A few of these, written in 1639, appear in Vol. III.; the documents of still earlier date, in Vol. XXV., may have formed part of the gift made, in 1667, by Mr. H. Howard, of the Arundel Library.

It seems that the appellation "Royal Society" was first employed by John Evelyn in his translation of a work by Gabriel Naudé. This translation, which appeared in 1661, is accompanied by a dedication to Edward, Earl of Clarendon; in this Evelyn writes: "God has Enlightn'd your great Mind with a Fervour so much becoming it in the promoting and encouraging of the Royal Society."

These guard-books may be properly called "classified papers," since the contents are generally arranged according to subject; the chronological order has also been observed in most cases. The collection comprises original papers and also letters or memorials communicated either to the society or to its officers or members; to these are added memoirs and reviews relating to the papers and a few broadsides and prospectuses. A large part of these papers have never been printed, and 2,500 have been indexed as to authors' names, of which there are more than 800; a few, however, are anonymous. Each volume of the guard-books now contains a table of contents and the names of the authors as far as they are known; as the articles are grouped under different subjects in most of the guard-books, a subject-index is not absolutely necessary.

It is impossible in this short note to give any adequate idea of the variety and importance of the papers contained in this collection, to the mathematician, physicist, mineralogist, zoologist, geographer, archeologist, in fact to all scientific workers who are interested in the classics of their particular science. One of the most interesting contributions was a sealed paper by the Hon. Robert Boyle on his "Way of makeing the Phosphorus." There are 103 papers by Robert Hook, 66 by Francis Hauksbee, 84 by Denis Papin and 19 by Sir Robert Moray. Among the other noteworthy names we may mention Isaac Borrow, John Hadley, Sir Hans Sloane, Sir Christopher Wren, Sir Isaac Newton, Giordano Bruno, Andreas Celsius, J. C. A. Helvetius, De Maupertuis, G. E. Rumphius, Prince Rupert, Carolus Linnæus, Athanase Kircher, Cotton Mather, D. G. Fahrenheit, etc.

The guard-books reflect great credit on the thoughtful care and foresight of those who for so great a period have maintained the dignity of the Royal Society and have preserved, not only the manuscripts of the author, but in many cases the entire correspondence on the paper.

Herewith the index to the twenty-five guard-books:

Volume.

I. Arithmetick, Algebra, Geometry, Trigonometry.
II. Surveying, Opticks, Perspective, Sculpture, Painting, Musick, Mechanicks.
III. (1) and (2). Mechanicks, Trades.
IV. (1) and (2). Physiology, Meteorology, Pneumaticks.
V. Journals of the Weather.
VI. Staticks, Hydrostaticks, Hydraulicks, Hydrology.
VII. (1) and (2). Architecture, Ship-Building, Geography, Navigation, Voyages, Travels.
VIII. (1) and (2). Astronomy.
IX. (1) and (2). Mineralogy, Magneticks.
X. (1), (2) and (3). Botany and Agriculture.
XI. (1) and (2). Pharmacy and Chymistry.
XII. (1) and (2). Anatomy and Surgery.
XIII. Monsters; Longevity.
XIV. (1) and (2). Physick.
XV. (1) and (2). Zoology.
XVI. Gramar, Chronology, History and Antiquities.
XVII. Miscellaneous Papers.
XVIII. (1) and (2). Experiments of Papin, Hauksbee and Desaguliers.

XIX. Inquiries and Answers.
XX. Dr. Hook's Papers.
XXI. Halley's Papers.
XXII. (1) and (2). Accounts of Books.
XXIII. (1) and (2). Inoculations.
XXIV. Papers by Collins, Oldenburg and Hook.
XXV. Political: Trade.

GEORGE F. KUNZ

SCIENTIFIC JOURNALS AND ARTICLES

THE July number (volume 8, No. 3) of the *Transactions of the American Mathematical Society* contains the following papers:

J. W. YOUNG: "General theory of approximation by functions involving a given number of arbitrary parameters."

E. R. HEDRICK: "On derivatives over assemblages."

BEPPO LEVI: "Geometrie proiettive di congruenza e geometrie proiettive finite."

OSWALD VEBLEN: "Collineations in a finite projective geometry."

R. L. MOORE: "Geometry in which the sum of the angles of every triangle is two right angles."

O. VEBLEN and J. H. MACLAGAN-WEDDERBURN: "Non-desarguesian and non-pascalian geometries."

L. E. DICKSON: "Modular theory of group-matrices."

OSKAR BOLZA: "Existence proof for a field of extremals tangent to a given curve."

G. A. BLISS: "A new form of the simplest problem of the calculus of variations."

A. E. YOUNG: "On certain isothermic surfaces."

The Library Journal for July contains an article on "The Library and the Museum," by Henry L. Ward, in which he takes the ground that a union of the two is impracticable, that the two differ radically in their methods and administration and that all attempts to unite them have been failures so far as the museum part is concerned.

Bird-Lore for July-August contains articles on "A Southern California Aviary," by H. L. Sefton; "A Report on the Nesting Birds in the Vicinity of Riverview Park, Allegheny, Pa., for 1906," by W. G. Pitcairn, comprising 95 nests of 20 species, 43 nests turning out successfully in spite of the small boy. F. H. Herrick contributes the first half of a paper on "Bird Protection in Italy as it impresses the Italian"; apparently it does not on the whole impress him favorably, for he considers that all birds should be killed and eaten, an idea he tries to carry into practise here. W. W. Cooke contributes the fourth paper on "The Migration of Thrushes" which consists mainly of a fine colored plate. There are "Notes on the Starling," predicting that the importation of this bird will be as greatly deplored as that of the English sparrow. There are important articles on the failure of New Jersey to pass a bill prohibiting spring shooting and on the failure of the bill to permit the sale of certain species of foreign game in New York. William Dutcher makes a strong plea for the preservation of the wood duck, showing that unless radical steps are soon taken the bird will be exterminated.

SOCIETIES AND ACADEMIES

THE NORTH CAROLINA ACADEMY OF SCIENCE

THE North Carolina Academy of Science held its sixth annual meeting at Chapel Hill, N. C., May 17 and 18, 1907.

The academy was called to order by its president, Collier Cobb, and an address of welcome was extended to the academy by President Francis P. Venable of the university. A response to the address was made by the retiring president, John F. Lanneau, of the Academy of Science.

In the evening the academy met in Gerrard hall, and the presidential address "The Garden, Field and Forest of the Nation" was delivered. Following this address a reception was extended to the visiting members in the Y. M. C. A. building. Saturday, May 18, at 9 A.M. the academy convened for a business meeting. Twenty-one new members were elected. The following officers were elected for the ensuing year:

President—T. Gilbert Pearson, of Greensboro, N. C.

Vice-president—W. C. Coker, of Chapel Hill.

Secretary—E. W. Gudger, of Greensboro.

Members of the Executive Committee—Franklin Sherman, Jr., of Raleigh; J. J. Wolfe, of Durham, and John F. Lanneau, of Wake Forest.

The report of the treasurer showed a balance of $122.53.

The following papers were presented:

The Sparsity of the Stars, the Measureless Remoteness of each Star from All Others: John F. Lanneau, Wake Forest College. The paper will appear in full in *Popular Astronomy.*

The Foundations of Geometry: Archibald Henderson, of the University of North Carolina, published in the *Journal of the Elisha Mitchel Society,* 1907.

Some New Sources of Light: C. W. Edwards, Trinity College. Read by title.

Some Interesting Grasshoppers (and their Relatives) of North Carolina: Franklin Sherman, Jr., state entomologist.

He mentions the following species: *Labidura Riparia, Cryptocercus punctulatus, Stagomantis carolina, Diapheromera femorata, Eritettix navicula, Trimerotropis saxitalis, Leptysma marginicollis, Melanoplus punctulatus, Dissoteiria carolina, Gryllotalpa borealis, Myrmecophila pergandei, Tridactylus* sp.

Osteogenesis Imperfecta (with a report of a case): Lewis M. Gaines, of Wake Forest College. Read by title.

Notes on the Cultivation of Algæ for Class Use: F. L. Stevens, of the N. C. College of Agriculture and Mechanic Arts.

Suggestions were given for the isolation and cultivation of algæ upon solid medium, consisting of .75 per cent. agar made up with Knopf's solution. This medium solidifying at lower than 34° can be safely used in plating out algæ. Cultures of several forms were exhibited.

Fusion of Sponge Larvæ with Formation of Composite Sponges: H. V. Wilson, of the University of North Carolina.

The ciliated larvæ of silicious sponges (*Stylotella*) may be made to fuse, thus giving rise to composite sponges. To accomplish this result it is only necessary to bring the larvæ in close contact at the time when the ciliary action is no longer locomotory and fixation is about to occur. The composite masses representing (in the actual experiments) from two to six larvæ complete the metamorphosis.

Wind-polished pebbles, and Palæolithic Man: Collier Cobb, of the University of North Carolina.

The close similarity between wind polished pebbles and work of man was indicated, and the errors which might result were pointed out.

Notes on Zoology of Lake Ellis: C. S. Brimley, Raleigh, N. C.

The paper discusses the occurrence of various insects and reptiles taken by the writer and others in the vicinity of Lake Ellis, Craven County, N. C., during June, 1905, and May, 1906. The rare salamander, *Stereochilus marginatus,* which had not been taken for many years was found to be common, and several specimens of the frog, *Rana virgatipes,* were taken. Nine alligators were secured on the two trips by the author's companion, and several rare snakes. Five species of dragonfly new to North Carolina were secured, and (in June, 1905) numerous specimens of the yellow fly (*Diachlorus ferrugatus*). Notes on other members of the Tabanidæ are also given.

Single Phase Railway Work: F. E. Latta, of the University of North Carolina.

The Relation of the Cattle-tick to Southern Agriculture: Dr. Tait Butler, State Veterinarian, Raleigh, N. C.

The Design of High Masonry Dams: William Cain, of the University of North Carolina.

Three Little-known Species of North Carolina Fungi: J. G. Hall, of the N. C. Experiment Station.

These are of some interest because one is a new species and another has not been reported in print in the United States.

The first is ***Martensella pectinata,*** Coem, a hyphomycete described in 1863 and is characterized by procumbent sterile hyphæ and erect fertile hyphæ. The fertile hyphæ bear short, lateral branches which become the sporophores.

The sporophores are naviculate and bear the fusiform-cylindric hyaline spores upon

basidia all over their face. The face is turned outward from the main hyphæ.

The second species is one of the genus *Epicoccum* also a hyphomycete and was interesting because it showed different colors of mycelium when grown upon different media.

The last species is one of the Pyrenomycetes and belongs to the genus *Podospora*. Its chief interest lies in the fact that the spores are joined in pairs by a non-septate hypha, thus coming very near podospora zygospora.

A New Form of Achlya: W. C. COKER, of the University of North Carolina.

During the fall of 1906 an *Achlya* was found at Chapel Hill, N. C., which agrees with *Achlya racemosa* var. *stelligera* Cornu in many respects, but different from it in having the antheridium cut off immediately below the oogonium, and the fertilizing tube arising from the division wall and entering the oogonium from below, as in *Saprolegnia hypogyna* Pringsheim. Such an origin for the fertilizing tube is new for the genus *Achlya*, and is not known elsewhere except in *Saprolegnia hypogyna*.

Notes upon the Preparation of the Silicate Medium for the Cultivation of Bacteria: J. C. TEMPLE, N. C. Agricultural Experiment Station.

Directions were given for the preparation of this medium obviating the necessity of dialyzing, and making it possible to prepare this medium with greater certainty and greater accuracy. The use of the medium prepared in this way for the culture of various organisms was illustrated by colonies of various bacteria growing in a thriving condition upon the medium.

Breeding Colonies of Birds (illustrated with eggs and stereopticon views): T. GILBERT PEARSON, of Greensboro.

The Efficiency of Soil Inoculation in the Production of Root Tubercles: F. L. STEVENS, of the N. C. Agricultural Experiment Station.

Data were given concerning the inoculation of soils with liquid cultures obtained from the Department of Agriculture, Washington, D. C. From many tests conducted in various ways there was no evidence whatever that inoculation with these cultures was efficient in the production of tubercles upon legumes. The cultures employed were issued in liquid condition in hermetically sealed test-tubes, and were obtained directly from the Bureau of Plant Industry, Washington, D. C.

The Opportunities for Study and Research at the Beaufort Laboratory: H. V. WILSON, of the N. C. University.

Does Blood Tell? Heredity according to the Experience of the Children's Home Society: WM. B. STREETER, of Greensboro, N. C.

Probably the most difficult proposition one engaged in child saving has to contend with is the firmly grounded belief in the principle of heredity; that as father, so son; as mother, so daughter. Almost adamantine is the conviction that 'blood will tell' but will it? If the question refers merely to mental and physical qualities, those things which depend upon physiological causes, undoubtedly the answer will be 'yes.' If it refers to moral tendencies, my experience covering a period of twenty years with children born under unfavorable conditions, leads me to answer the question in the negative. As children of my experience were recovered from the custody of vicious parents at an early age, and reared in the atmosphere of moral uprightness, have almost invariably reached their majority in the state of voluntary social purity, I conclude that it is the heredity of environment, rather than the heredity of blood, that determines moral character.

Geology of the Cape Fear River: JOSEPH E. POGUE, of the University of North Carolina.

The Relation of Sporangium of Lygodium to the Evolution of the Polypodiaceæ: RAYMOND BINFORD, of Guilford College. To be published in the *Botanical Gazette*.

The Condensation of Aliphatic Aldehydes with Aromatic Amines: ALVIN S. WHEELER, of the University of North Carolina.

The following reaction takes place without any dehydrating agent: $RCHO + 2RNH_2 = RCH(RNH)_2 + H_2O$. In some cases at low temperatures the addition product is ob-

tained. Condensation products of Chloral with the three nitranilines, p-bromaniline, o-toluidine, anthranilic acid, and o-anisidine were prepared. By-products, as yet unidentified, were obtained with o-toluidine and with anthranilic acid. The condensation products are readily broken down by hydrochloric acid and by acetic anhydride. When suspended or dissolved in the glacial acetic acid they react with extreme smoothness with bromine, forming beautifully crystalline compounds which are much more stable than the condensation products.

Chapel Hill Ferns: W. C. Coker, of the University of North Carolina.

A collection of the living ferns and fern allies native to Chapel Hill, N. C., was made and exhibited in pots. Twenty species were represented, including all the known Pteridophytes of the neighborhood, except *Botrychium ternatum* and its variety, *dissectum*, which had not yet appeared above ground.

Notes on Turtles of Genus Pseudemys: C. S. Brimley, of Raleigh, N. C.

This paper discusses the character of the turtles of this genus and shows that the distinctive characters attributed to *P. hieroglyphica, P. Labyrinthica, P. mobilensis* and *P. Concinna* all fall within the limits of individual variation of the last named form. These conclusions are drawn from an examination of all specimens of the genus that have passed through the author's hands for the last five or six years.

Electricity in Heavy Traction (illustrated by lantern slides): J. E. Latta, of the University of North Carolina.

The Design of High Masonry Dams: William Cain.

The claim is made that in addition to the three universally imposed conditions, no tension, safe unit pressures and no possible sliding at any horizontal joint, a fourth condition must be imposed, *viz.*, that the factors of safety against overturning and sliding shall increase gradually from the base upward, to allow for the proportionately greater influence, on the upper joints of the wind and wave action, floating ice or other bodies, and especially of the great forces caused by the expansion of thick ice under an increase of temperature, and by earthquakes.

It was found that this could easily be done by taking the well-known theoretical triangular type of cross-section of dam and making some additions at the top sufficient for a roadway.

A preliminary design is given for a dam 258 feet high, with factors of safety and unit pressures marked on the drawing, satisfying all four conditions, the area of cross-section and height being the same as for the celebrated Quaker Bridge design. A comparison was instituted unfavorable to the latter, in that its factors of safety are too small, particularly in the upper portions, where by the proposed fourth condition they should be largest.

This criticism owes its significance to the fact that the new Croton Dam, of New York, 224 feet high to water surface and finished February 1, 1906, at a cost of over $7,500,000 has a profile for 224 feet in depth, exactly the same as the quaker bridge design for the same depth.

The Optical Rotation of Volatile Oil: C. H. Herty and G. A. Johnson, of the University of North Carolina.

Children's Home Society Methods: Wm. B. Streeter, of Greensboro.

Gametophytes of Botrychium Virginianum: Raymond Binford, of the University of North Carolina.

They were found in moist oak woods under the leaves. Some were almost on the surface of the soil, while others were imbedded one to two inches in the soil. They seem to have gotten down by means of worm holes or cracks made by roots of trees. Sizes ranging from 2 mm. to 10 mm. were shown. Specimens of these plants were exhibited before the academy.

F. L. Stevens,
Secretary

DISCUSSION AND CORRESPONDENCE

SEEING THE LIGHTNING STRIKE

On July 14, 1907, at about 5:30 P.M., for the first time in my life, I saw the lightning

strike. I was at a window in the university building, looking westward toward a valley, at the center of which, about a quarter of a mile away, there was a field with a few isolated trees. A thunderstorm coming up slowly from the southwest gave me hopes of seeing the lightning strike. I saw it strike one of these trees. The flash appeared to me as a superb column or shaft of light, about four or five hundred feet high, and about eight or twelve inches in diameter, perfectly straight, vertical and steady. The shaft was white, the base, however, was distinctly red, like the fire of a conflagration, and tinged probably with a little orange. This column of light seemed to stand between the two diverging stems of the tree. It lasted for about two seconds. The thunder was loud, but not the loudest I have ever heard. A light rain was falling at the time.

The effects of the flash seemed to be none whatever. The tree was not shattered and was not set on fire. Some cows grazing about a hundred feet away paid no attention to the discharge, except one which walked toward the tree, as if interested in something there, and then turned around and continued to graze.

The next morning I examined the spot closely. The tree was a cottonwood and stood in moist ground. It consisted of two trunks, about eight and twelve inches in diameter, diverging from a common base towards the north and south. The southern or smaller one had the bark stripped off its western side, in the shape of a broad ribbon, about two yards long and six inches wide. The east side showed two furrows starting from above the same branch, about ten feet above the ground, and running downward in irregular paths. These furrows seemed to have been plowed by a piece of steel and the bark torn off by violence, because there was no sign of scorching or any change of natural color. There was absolutely no other noticeable effect. I was told that a horse standing near the tree had been thrown over a fence, badly stunned but not otherwise injured.

WILLIAM F. RIGGE
CREIGHTON UNIVERSITY

SPECIAL ARTICLES

THE METHOD OF TRIAL AND THE TROPISM HYPOTHESIS

IN his recent book entitled "Behavior of the Lower Organisms" Professor Jennings has drawn attention to the existence of an issue between two attitudes assumed by investigators in attempts to interpret the behavior of organisms. His own position is made sufficiently clear. He is frankly hostile to what he conceives to be the essentials of the tropism hypothesis, and is equally devoted to what he has called the "method of trial" as a means of explaining facts for whose interpretation he believes the tropism hypothesis to be entirely inadequate.

My reason for venturing upon the present discussion of the issue thus emphasized lies in the fact that, while I have been much impressed by the admirable plea which Professor Jennings has made for the method of trial, I do not quite see the force of his main contentions, as applied either to the destruction of the tropism hypothesis or to the support of its successor.

The value of any hypothesis may be estimated according as it does or does not (1) accord with the facts, (2) simplify the problem to be solved, (3) suggest a new line of advance. These tests may be applied to the hypotheses that at present concern us. The views of Professor Jennings will be considered first.

Professor Jennings attempts to account for the phenomena of organic behavior on the basis of two principles. According to one, "behavior is based fundamentally on the selection of varied movements." According to the other, "the resolution of one physiological state into another becomes readier and more rapid through repetition." These are the "primary facts for the development of behavior." Given organisms that react to changes in their environment, given a variety of responses to the same conditions, and the material is provided for the development of all types and grades of organic behavior in accordance with the two principles just stated.

This is obviously a strict application to the

phenomena of behavior of that variant of the Darwinian doctrine known by the name of organic selection. It is a view that lends itself with especial facility to the interpretation of physiological evolution. It distinguishes between adaptations that are relatively unstable, resulting from the capacity of given individuals to accommodate themselves to changing conditions, and adaptations that are relatively stable, such as the inherited adaptations characteristic of races. Its chief contribution to the present discussion lies in the recognition that acquired characters, such as habits, cultivated aptitudes, advantages obtained over competitors by larger experience, may be approved by natural selection, even though heredity decline to place them on a permanent footing. Fortunate individual adaptations of the unstable variety come then to play important rôles in the preservation of the species, and in one sense actually determine the course of its evolution. Such, at least, is the claim of the organic selectionists with whom Jenings allies himself, and I have no wish to deny the hypothesis.

How the organism comes into accord with its environment to the extent that it is able to persist is determined, according to Jennings, primarily by application of the method of trial. The individual itself selects those reactions which are favorable for its existence from a number of random or trial reactions. Let us consider a typical case. Whenever the protozoon *Paramecium,* swimming along its narrowly spiral path by means of the vibratile hair-like cilia that clothe its body, chances to come in contact with an impediment, whether it be in the shape of a sand grain, a droplet of some chemical solution or a sudden change in temperature, the beat of its cilia may be reversed and it may back off for a distance varying with the strength of the stimulation. Another reversal of the cilia then sends it forward again, but not quite in the direction it had previously taken. Owing to the peculiar beating of its cilia, its progress is along a spiral path, with the primitive gullet (hence a structurally defined side) always towards the axis of the spiral. On resuming a forward movement, the creature swerves toward the side away from the mouth. This has been described as an avoiding reaction, since it provides a method of passing obstacles. The method is said to be a method of trial. *Paramecium* backs and fills until it chances to hit upon an unobstructed pathway. No cause of a reversing reaction being offered, it keeps on its way. Its final appropriate reaction is said to be selected from a number of inappropriate trials or errors.

How far the facts obtained from an analysis of the behavior of *Paramecium* are applicable to the analysis of behavior in general may best be considered after an examination of Jennings's scheme according to which behavior develops, that is, becomes more effective:

> The behavior of any organism may become more effective through an increased tendency for the first weak effects of injurious or beneficial agents to cause the appropriate reaction; in other words, through increased delicacy of perception and discrimination on the part of the organism. Such a change would be brought about through the law of the readier resolution of physiological states after repetition. When the organism is subjected to a slight stimulus, this changes its physiological state, though perhaps not sufficiently to cause a reaction. Such a slight stimulus would be produced by a very weak solution of a chemical, or by a slight increase in temperature. Now, suppose that this weak stimulus, causing no reaction, is regularly followed by a stronger one, as would be the case if the weak chemical or slight warmth were the outer boundary of a strong chemical solution, or of a region of high temperature toward which the organism is moving. This stronger stimulus would produce an intense physiological state, corresponding to a marked negative reaction. That is, the first (weak) physiological state is regularly resolved by the action of the stimulating agent into the second (intense) one, inducing reaction. In time, the first state would come to resolve itself into the second one even before the intense stimulus had come into action. As a result, the organism would react now to the weak stimulus, as it had before reacted to the strong one. It would thus be prevented from entering the region of the chemical or the heat, even before any injury had arisen.
>
> 2. In the same way the organism may come to react positively or negatively to a stimulus that is

in itself not beneficial nor injurious, but which serves as a sign of a beneficial or injurious agent, because it regularly precedes such an agent.

This proposition is illustrated by the approach of an enemy which casts first a faint, later a deeper shadow. The organism comes to react to the faint stimulus.

3. Progress takes place through increase in the complexity and permanence of physiological states, and in the tendency to react to these derived and complex states instead of to the primitive and simple ones. . . .

4. Progress in behavior may take place through increased variety and precision of the movements brought about by stimulation.

New movements, even new organs, such as flagella, might be acquired by the selection of overproduced movements and of overdeveloped structures whose movements become advantageous.

Thus through development in accordance with the two principles mentioned, the organism comes to react no longer by trial, by the overproduction of movements—but by a single fixed response, appropriate to the occasion. . . . Such fixed responses are the general rule in the behavior of higher organisms, and are found to a certain extent in all organisms. In the higher organisms we speak of some of these fixed responses as reflexes, tropisms, habits, instincts.

This is, in brief, the general course of the development of the behavior of single individuals.

Recognizing the dangers in attempting to state adequately the position of an author in this fragmentary fashion, I feel confident I do him no injustice (1) in calling attention to his assertion that fixed responses, such as reflexes, tropisms, habits, instincts, are developed through selection from overproduced random movements by means of the method of trial; (2) in noting that the substances suggested as agents of stimulation all initiate reactions of the tactual type. Reaction takes place on contact, the essential stimulus being the abrupt change produced by the contact and depending qualitatively not at all on the character of the object touched.

No one, I am sure, would doubt that the behavior of an organism rests somewhere on a basis of physiological change. Such changes, however, may be of various kinds, involving various groups of factors and giving rise to various types of reaction. That definitely directive reactions are reducible to the motor reaction type, as seen in its essential features in *Paramecium,* is a conclusion that does not appear to follow from the present accessible facts of behavior. Though the selection of overproduced movements by trial may account for certain types of behavior, I do not see how it accounts also for definitely directive or tropic reactions. It is not clear that the latter belong in the category of secondary, rather than primary reactions, notwithstanding Professor Jennings's vigorous endeavors to put them there. My difficulties are soon stated.

Any one who has stimulated excised muscle from a freshly killed animal by means of a galvanic current, is aware that its behavior at the moment the current is made or broken is quite different from its behavior during the continuous passage of the current. It is well known that this difference is to be referred first of all to the fact that the make and break responses are caused by sudden changes in electrical potential, which changes do not accompany the passage of the constant current. Further, the reactions of many organisms without muscles to galvanic stimulation exhibit parallel differences. Indeed, it has been determined that the behavior, under galvanic stimulation, of such an organism as *Paramecium,* accords in many essential details with the laws and theories originally formulated with reference to the reactions of the muscles of vertebrates. The passage of the constant current through a muscle may produce a tonic contraction at the kathode, not, however, at the anode. In *Paramecium,* a similar condition expresses itself in the behavior of the cilia. *Paramecium* can be made to turn with the utmost definiteness and directness until its anterior end is toward the kathode. When finally oriented, it is still clearly affected by the stimulus. For the behavior of the cilia at opposite ends of the body, normally uniform, is in this case different.

In this brief résumé of some phenomena

connected with galvanic stimulation, the following facts should be noted: (1) that the phenomena of galvanic stimulation present certain important correspondences with respect both to vertebrate muscle and free-swimming unicellular organisms; (2) that galvanic stimulation is of two kinds and produces two different effects, the constant current producing a definitely directive orientation effect (galvanotropism); (3) that the stimulating effect of the constant current does not cease with the establishment of the permanent orientation. A further fact should be added, namely, that galvanic stimulation is practically unknown in nature.

These facts would appear to lend support to the tropism hypothesis. Professor Jennings, however, believes that the very uniqueness of the electric stimulus in producing its peculiar local effects upon the organism, and its practical absence from nature, vitiate its claims to consideration in any attempt to formulate a universal explanation of the behavior of organisms.

It is not easy to see how, on such grounds, the interesting phenomena of galvanic stimulation are to be so lightly put aside. That a stimulus is unique in any respect is hardly ground for neglecting it. And that it does not occur in nature is for the candid analyst one of its most valuable assets. He thereby gets rid of the selection hypothesis and the mass of unestablished inferences which it has gathered to itself. He is free to examine types of animal behavior which never could have been produced by selection. He comes so much the nearer the fundamental responses of organized matter to at least one stimulus. And he finds, instead of the varied, haphazard reactions which are the only primary reactions for Jennings, two sorts of reactions, one of which is as definitely directive as any class of reactions in the organic world.

If organisms, without the aid of selection, respond definitely and directively to one sort of stimulation, whether in or out of nature, does that not at least raise a suspicion that definite directive reactions, wherever they occur, may also be interpreted without such aid? With such a suspicion in mind, we may examine some of the evidence from nature which has been counted for the trial and error schema.

From galvanic stimuli, then, we may turn to a consideration of the reactions of organisms to light.

In this field numerous investigators have been accustomed to distinguish between two types of reactions which parallel the two types of responses to galvanic stimulation. The first type depends upon rapid changes in the intensity of light and has been called Unterschiedsempfindlichkeit by Professor Loeb. Many years ago, he distinguished this type of reaction from the second or tropic reaction, finding it well exemplified among certain annelid worms that dwell in tubes from which the anterior ends of their bodies project. When the intensity of the light falling upon one of these projecting ends is rapidly diminished beyond a certain degree, the worm suddenly responds by contracting its longitudinal muscles and withdrawing into its tube. It is a significant fact that a corresponding increase in the intensity of the light falling upon an extended worm does not cause a contraction. Similarly, the unicellular *Stentor* passes from a brightly illuminated field into shadow without reaction, but reacts when it reaches the edge of the shadow in passing in the reverse direction.

Whether this difference in the response is directly comparable with certain observed differences in the effects produced by making and breaking the galvanic current we are not yet in a position to determine. That there is an obvious resemblance, however, between the reactions produced in organisms by a constant current and by continuous exposure to light can not be denied. Numerous animals orient themselves with the utmost definiteness and directness so that they may move toward or away from the source of light. Two cases may be examined, both of which Jennings places in the category of trial and error responses.

1. *Euglena* is a chlorophyll-bearing protist, with an asymmetrical body, a long flagellum arising from one end and a spot of pigment

near the base of the flagellum, which appears to be particularly sensitive to light. Like *Paramecium, Euglena* swims in spirals, and possesses a similar avoiding reaction, which follows not only upon stimulation by chemical and mechanical agents, but upon sudden changes in the intensity of light as well. Depending on the strength of the stimulation, the response may be a reduction of the speed of locomotion, a total stoppage, or, rarely, a reversal. Then there is a swerve toward a certain structurally defined side of the organism so that the spiral in which it swims becomes wider than before. It thus comes into a number of new positions with reference to the source of the stimulus. These, according to Jennings, are trial positions or orientations, and which one of them may be selected for the forward movement will depend upon the degree to which it lessens the stimulation which is inducing the trial movements. Continuous selections, based upon a continuous series of new trials, bring the organism finally into such an orientation that it proceeds toward the light around an axis of progression that passes through the latter.

The second case need but be mentioned. The rotifer *Anuræa* is a very small but very different organism from *Euglena*. Nevertheless, it moves also upon a spiral path and its reactions in the presence of light differ in no essential respect from the reactions of *Euglena,* except that the animals experimented upon by Jennings moved away from rather than toward the light. With this difference in mind, the same figure will serve admirably for both organisms (Jennings, Fig. 93, p. 137).

My analysis of their responses, based upon the figure which Jennings himself has drawn, with text description, leads to quite a different conclusion from his. The figure indicates that *Euglena* is both unterschiedsempfindlich and heliotropic. At *a,* the reversal in the direction of the light which has been coming from the direction in which the creature has been swimming produces a sudden change in intensity of stimulation, a shock which results in the swerving from the previous course as indicated between *a* and *c*. The organism recovers rapidly, only to be subjected to the constant stimulus of a steady light from one direction to the end of the experiment. The result of the action of the constant stimulus is a path, from *c* to 5, so perfectly in harmony with the tropic schema, that, in spite of Jennings's descriptions and elucidations, I can only wonder at his running so boldly and so far into the enemy's camp. It is hard for me to conceive how an organism swimming of necessity in a spiral course could react more definitely to a moderate directive stimulus than does *Euglena* here.

It will be noticed that orientation by the method of trial depends, according to Jennings, upon the selection of trial orientations that subject the organism to less and less effective stimulation; that when the final orientation is adopted, the organism is in an *unstimulated condition* with reference to the stimulus which had been acting up to this point. This is clearly the application in the field of light stimulation of the facts obtained by the observation of the reactions of such an organism as *Paramecium* to contacts. It is assumed (1) that the locomotion of *Paramecium* is a necessary result of its peculiar metabolism, and (2) that in the absence of perturbing influences in the environment, it may swim along a spiral course with a straight axis. These assumptions may be granted without, however, admitting thereby the converse, namely, that when the axis of progression is a straight line *Paramecium* is necessarily free from the influence of external stimuli. It does not appear self-evident that as soon as *Euglena* becomes oriented so that its axis of progression passes straight toward the source of light it ceases to be stimulated, to be again stimulated only when it chances to swerve out of that course.

For Jennings there is nothing comparable to symmetrical stimulation in the field of organic behavior. There is likewise nothing comparable to a constant stimulus that does not induce a differential movement. This is as much as to say that an object which is subjected to equal degrees of pressure from diametrically opposite directions is not being

affected thereby until perchance the pressure on one side becomes less than the pressure on the other. Or, to draw a parallel from the field of organic behavior itself, it has been determined by many investigators that when, instead of a single source of light, two sources of equal intensity, such as two incandescent lights, are placed symmetrically before phototropic organisms, the latter may move toward or away from them along the perpendicular, passing through a point midway between them. When one light is cut out, the organisms may change their direction at once, moving toward or away from the remaining light. According to Jennings, they are not in a condition of stimulation while moving toward or away from the two lights, but only during the period between the removal of one light and their orientation to the light remaining. Jennings denies emphatically the possibility of symmetrical stimulation in such a case.

Now it has been shown already that the constant galvanic current does produce observable constant effects in organisms which are moving directly toward one pole. It is also well known that certain organisms (*e. g.*, newly hatched barnacle larvæ) after exposure to light for a time, during which they may move toward the light, may change the sense of their response, moving in the opposite direction. There is no doubt that we are dealing here with a physiological effect produced by a constant stimulus that occurs commonly in nature, and that this effect conditions a definitely directive response. Yet, though this sort of behavior is cited in another connection by Jennings, its significance in the present connection is not considered.

But let us consider briefly one other class of facts which receive no consideration in Jennings's book. It is well known that certain phototropic crustacea and insects, when robbed of the use of one eye by a coat of opaque varnish, perform what have been called circus movements. They move in circles in the presence of light, toward or away from the functioning eye according as they are negatively or positively phototropic. These movements are just what would be expected from a phototropic animal that can receive light stimulation only through its eyes, when one eye is kept constantly in the shade. They are in entire accord with the tropic schema. Now it happens that hemisection of the brain causes the phototropic reaction to disappear in certain Amphipods on which the operation has been performed, although unilateral injury of the brain does not interfere with the phototropic response. That these facts are to be explained on the assumption of a reflex of some sort between eyes and locomotor mechanism, and that one eye is connected with that part of the mechanism which operates one side of the body, while the other eye is similarly associated with the mechanism for the other side of the body, seems clear. The reactions of the leg muscles of *Ranatra*, when that animal is subjected to light stimulation alternately on the two sides of the body, change with the utmost definiteness, according to the position of the light with respect to the eyes. The response is unquestionably reflex and singularly definite and local.

To consider just one more case that will bring out still more clearly the difference between Jennings's conception of a stimulus and my own. When the semicircular canals on one side of the head of an animal are removed or injured, or the nerve supplying them is cut, the normal response to gravity will be disturbed. In man, sensations of unbalance would result, general sensations or feelings, such as discomfort, even distress. These are obviously psychical facts. So far as the injured man is concerned, reflex responses to gravity by way of the semicircular canals have never been noted. He has never suspected any mechanism in his body devoted to the task of keeping him physically upright. Accordingly, in the absence of the feeling of discomfort resulting from operation or injury, he may be said to be in a non-stimulated condition, *but only so far as the facts of consciousness are concerned.* Some such case is what Jennings appears to have in mind when he insists that a stimulus depends essentially on a change in condition. When an organism moves in a straight line toward or away from

a point midway between two lights of equal intensity that are equidistant from the organism itself, it does so, he believes, because in such an orientation it is subjected to no general stimulation, which is no more than saying it then possesses no feeling of discomfort. In the face of the facts which have been presented to show that light induces definite reactions of definite muscles, just as definite as the complex but unconscious reactions of a decapitated frog to, let us say, acetic acid applied to the skin of its back, he insists upon an interpretation of organic behavior by means of general changes in internal states that are psychical rather than physiological. Here, as it seems to me, he has abandoned one attempt at explanation for an alleged explanation which itself assumes the facts most in need of elucidation.

It will not be necessary to delay further by examining the phenomena of geotropism. Organisms respond to the stimulus of gravity by reactions essentially similar to those which characterize their reactions to light. No new elements are introduced. It may be well, however, to summarize the discussion up to this point before entering upon a somewhat different line of criticism.

Jennings has applied to the facts of behavior a general explanation in the form of two principles. According to these principles, no definitely directive or fixed reactions, such as reflexes, tropisms, habits and instincts are primary, but result from the selection from random movements of such as are advantageous to the organism, and the gradual development of these advantageous reactions in the individual by the law of the readier resolution of physiological states, in the race by the operation of organic selection. The primary type of reaction is non-directive, and is illustrated by some such response as the motor reaction of *Paramecium*. The necessary condition of stimulation is an abrupt change in the environment, which leads to a general reaction of the whole organism. What the adherents of the tropism theory call a condition of symmetrical stimulation is, therefore, in reality a condition of no stimulation at all. The existence of constantly acting directive stimuli after orientation is explicitly denied.

In our examination of this general view and the propositions on which it is based, we have arrived at the following preliminary conclusions:

I. That the essential facts of galvanic stimulation are identical in widely different organisms, which suggests their fundamental character; that there exist among the phenomena of galvanic stimulation two types of reaction, (1) non-directive, dependent on sudden changes of current potential, and (2) directive, dependent upon the action of a constant current which, it was shown, produces, after orientation an observable effect on locomotion; further, that the very fact of the pronounced absence of galvanic stimuli in nature greatly increases the value of galvanic stimulation as an aid to analysis.

II. That organisms exhibit toward light (gravity as well) two types of reaction comparable with those typical of galvanic stimulation; that certain responses, in *Euglena* and *Anuræa,* which are readily analyzed on the basis of these two kinds of stimulation, afford no support for the trial and error schema; that in heliotropism as well as in galvanotropism, the oriented organism is in a condition of physiological stimulation, and that the response to stimulation is local; finally, that the interpretation of the behavior of heliotropic organisms on the basis of general changes concerning the whole organism, not only does not accord with the known facts, but is rather psychical than physiological in character.

If these conclusions be sound, it follows that the method of trial, however useful it may be in the interpretation of certain classes of facts relative to the behavior of organisms, lends no aid toward the analysis of certain other classes of facts in the same field; that it not only does not simplify the general problem which these facts present; but that it actually tends to divert inquiry from a line of investigation which has been shown by recent achievements to be not only promising but fertile.

To these conclusions I believe we may justly add another that has not yet been formulated in the discussion.

If all definite directive responses to stimuli have been produced by the selection of responses "that favor the normal life processes" as Jennings appears to believe, then such directive responses must be adaptive, must be of distinct advantage to the organism possessing them in the struggle for existence. There are, however, among certain organisms and in connection with certain classes of stimuli definite reactions which do not appear to serve the organism in any way.

In the first place, the phenomena of galvanotropism are obviously not in any way related to a possible adaptive value. In the second place, Professor Loeb mentioned long ago the caterpillar of the willow borer, and *Diastylis* (*Cuma*) *rathkii,* as two animals that live away from the light, the one buried in the wood of trees, the other in the mud of bays and lagoons, that yet react positively when exposed to light. Such instances are brushed aside as insignificant by Jennings, because few have been recorded. I feel confident, however, that instances of this sort will multiply. And far from being insignificant, it is most fortunate for the analysis of behavior that, in a world where the struggle for existence is so intense, even a few organisms have been found whose behavior has remained unaffected by it.

I do not think it is necessary to go farther into the facts to make it clear that the hypothesis advanced by Jennings is not sufficiently broad to encompass all the phenomena it is devised to explain. As a method of analysis, it is essentially historical. It seeks to derive all forms of organic behavior from a simple type or unit assumed to be fundamental. We have seen, however, that the assumed fundamental unit is really not fundamental physiologically, since it is based squarely upon a psychological conception. The method, therefore, prescribes the interpretation of purely physiological phenomena, such as reflexes and tropisms, in terms of psychology. From the standpoint of effective analysis, this is surely putting the cart before the horse. The trial and error program looks very much like a modern recrudescence of the attitude toward the problems of behavior that could tolerate the interpretation of the behavior of a moth toward a flame as an exhibition of curiosity.

We may now examine somewhat more closely than has been possible so far, another interpretation, known by the name of "tropism hypothesis," which has been applied to certain aspects of the behavior of organisms and has been sharply attacked by Jennings. Far from pretending to be a universal formula, it has been suggested in various forms by various investigators for the purpose of testing the applicability to the problems of organic behavior of the data of physics and chemistry. It is a guide for analysis along experimental rather than historical lines, and in accord with its reason for being, is dependent upon no psychological data of any sort.

It has appeared from the preceding discussion that there is ground for believing in the existence of two classes of stimuli in nature, and that according to the tropism hypothesis both may elicit primary responses.

The view that the definitely directive responses known as tropisms are primary does not rest, however, merely on whatever presumptive evidence the curtailment of the trial and error program may admit. There are numerous examples in nature of the dependence of the tropic reaction upon the physiological condition of the organism. The larvæ of *Polygordius,* a marine annelid worm, when taken, are negatively heliotropic. Two hours later, they may be positively heliotropic. This change may be obtained immediately by cooling them down to a temperature of 7° C. The response may again be reversed by suddenly diluting the salt water containing the larvæ with one third to two thirds its volume of fresh water. The sense of the resulting response may in turn be reversed by increasing the concentration of the water. I have already referred to the barnacle larvæ that are positively heliotropic immediately after hatching, but, after a certain limited exposure to light, become negative. Terrestrial amphi-

pods which are positive, change the sense of their response when thrown into water. Many animals change the sense of their response to light with age and sexual condition. The larvæ of the king crab react positively in their earlier stages, negatively later. Maggots of the house-fly respond negatively at the end of their larval period, but are quite indifferent to light both before and after this stage in their existence. At the time of sexual maturity, both ants and bees have exhibited positive responses to light.

Further, it is a highly interesting fact that certain caterpillars, notably *Porthesia chrysorrhœa,* are positively heliotropic when starved, unresponsive when well fed. The suggestion at once arises that the diffusion of chemical substances into the body from the digestive canal may cause the modification of the reaction. Acting on the hint here given, Professor Loeb initiated a series of experiments to see whether the immediate effect of the light in causing the heliotropic reaction is of a chemical nature. Such a supposition could be put to the test by placing heliotropic organisms in an artificial chemical environment. The results of experimentation in this direction have been productive of the most important results. *Gammarus, Daphnia* and *Cyclops,* all freshwater crustacea, were used. *Gammarus pulex* is, if anything, negatively heliotropic. By the addition to the water containing a number of individuals of this species of slight amounts of various chemical substances—esters, hydrochloric, acetic, oxalic and carbonic acids (the last itself a product of the metabolism of the animal), alcohol, paraldehyde and ammonium salts—in each case the animals become positively heliotropic. Similarly, *Cyclops,* either negative or indifferent, may be made positive by the addition of hydrochloric acid or carbon dioxide.

It is clear from the facts just recited that the heliotropic reaction of an animal is not necessarily constant, but that it may vary widely and suddenly in sense, or disappear altogether, in accordance with internal changes which are immediately chemical in character. There is little in such phenomena to suggest that tropic reactions are products of carefully selected trial movements. On the contrary, they suggest most strongly the possibility of identifying such reactions with de Vriesian mutations.

With the demonstration that chemical changes are connected in an important way with the reactions of organisms to light, the analysis of the tropic reaction has only begun. Recent experiments have achieved further results. I may quote, in translation, from a recent paper by Professor Loeb:

> It might be assumed that acids call forth positive heliotropism among fresh water organisms because they accelerate the formation of a certain substance upon which the positive heliotropism depends. This conjecture, however, can be disproved. We know, namely, that reaction velocity increases with the temperature, and that the temperature coefficient is in these cases very high, namely, in general for each 10° rise in temperature $\geqq 2$. Now I determined for freshwater copepods how large the minimal amount of carbonic or acetic acid is that is necessary to make indifferent animals positively heliotropic. It became apparent that for temperatures of about 10°–15°, not more but actually less acid is required to call forth positive heliotropism than at 20°–25°. That shows that the acid in this case can not act through the formation of a substance that conditions positive heliotropism. A similar experiment resulted even more strikingly for *Daphnia.* Here a fall in temperature below that of the room lessened in the clearest way the amount of acid necessary for the production of positive heliotropism. Now it appears to be generally the case, that when the temperature influences especially the sense of heliotropism in animals, this, so far as at present known, always happens in the sense of making it more positively heliotropic. We can accordingly draw the conclusion with absolute safety that the production of positive heliotropism is not due to an acceleration in the formation of a positive heliotropic substance—to use an expression which may be permitted for the sake of brevity. Rather are we forced by all these facts to the conclusion that the production of positive heliotropism in animals by means of acids rests upon the inhibition of the formation or action of an antipositive substance. It is conceivable that the conditions of positive heliotropism (therefore the positive heliotropic substance) are present in the organisms that here interest us, that, however, their

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(photochemic?) activity is inhibited by the continuous formation of certain stuffs in the body, *e. g.*, in the eyes. If, now, we assume that acid inhibits the formation of these latter antibodies, then the positive effect of the acid is intelligible. Just so is the positive effect of the fall in temperature intelligible, since thereby the rapidity of the formation of the inhibitive antibodies is diminished.

Though the nature of the substances connected with the heliotropic reaction is not definitely known at present, experiments have suggested strongly that they may be of the nature of oxidases. Researches soon to be published confirm this view in a striking manner.

These facts still further emphasize the improbability of the production of tropic reactions as the result of the selection of a series of trial movements; while they further emphasize the probability that such reactions, dependent upon the presence of definite chemical substances, have sprung suddenly into existence in the manner of the mutations of de Vries. As such, they provide material for natural selection, along with every other variation, whenever they tend to preserve the life of any organism in its struggle for existence.

It has already been said that both Unterschiedsempfindlichkeit and heliotropism (or some other tropism) may be associated in the same organism. Such cases are common, and in every one of them the possibility of confusing the two reactions (as shown for *Euglena*) exists. To cite but a single instance, certain positively heliotropic butterflies will not move toward the brightest light when their bodies chance to be in contact with a pane of glass under which they have crept. Furthermore, a weak light may produce no reaction upon organisms where a light of greater intensity would. It often happens that under a light stimulus too weak to produce its appropriate definite directive effect, an organism may waver about, swinging now toward, now away from the source of the stimulus. These have been called trial movements. I do not believe they belong in that category, for two reasons. In the first place, when the organism comes into a proper orientation for an organism whose line of least resistance runs toward the light, it does not stay so oriented. In the second place, when the light is sufficiently strengthened, the organism may make for it with the utmost directness.

The earthworm, a much used and abused animal in this connection, has recently afforded a case in point. *Perichæta* is an unusually active worm, and reacts, as all earthworms do, negatively to light. To quote from Harper:

> 2. The body is less sensitive to light when contracted than when extended, owing to the fact that when extended the sensitive elements are spread out over a greater surface and become more susceptible.
>
> 3. In locomotion, as there are alternate extensions and contractions, there is an alternation of the condition of lower and higher sensibility. This is important particularly in the sensitive anterior end.
>
> 4. As the worm begins each extension in a condition of lower sensibility, it may project its anterior end toward the source of light. This movement is checked as soon as the increased sensibility of the extended anterior end appreciates the stimulus. Movements away from the light do not meet such a check and so are prolonged farther. Orientation is the result of a trial and error method.

Up to this point the reaction comes under the head of Unterschiedsempfindlichkeit.

> 5. In strong enough light, random movements toward the light are suppressed altogether, and the worm appears to move directly away from the light without noticeable trial movements. This applies to worms which have been kept in the dark and are in a perfectly fresh condition, as after a time they lose their discrimination and begin to make random movements.

This section should be noted, especially the last sentence. Just as it has been seen that larvæ of barnacles may change their response when exposed for a time to light, so *Perichæta* becomes, after a certain exposure, indifferent to stimulation that produces a typical heliotropic reaction in the fresh worm. The animal remains, however, unterschiedsempfindlich. It contracts whenever, by extension of the anterior end, a sufficiently large sensitive area is exposed to the light. In *Perichæta*,

therefore, not only do the two types of response occur, but prolonged exposure to light eliminates the possibility of one without interfering with the other. It is difficult to see how responses that are not different in kind could be distinguished in this manner.

In closing, it will not be necessary to summarize again the elements of the schema that Jennings has proposed for the interpretation of the behavior of organisms nor the objections which it has seemed to me could be urged against it. There is no doubt that by his very serious discussion of the problems of behavior, Professor Jennings has done the great service of focusing attention upon the essentials and the unessentials, understandings and misunderstandings in this field of investigation. And I offer the foregoing discussion, originally prepared for a non-biological audience of scientific men, in response to the invitation which is implied on many pages of his book.

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April 8, 1907

BOTANICAL NOTES

WOOD-STAINING FUNGI

IN the September number of the *Journal of Mycology* George G. Hedgcock publishes a descriptive list of twenty fungi which stain different kinds of woods, in some cases so injuring the appearance as to cause much damage. Eight species of *Ceratostomella,* seven of *Graphium,* one of *Fusarium,* two of *Hormodendron,* one of *Hormiscium* and one of *Penicillium* are listed and described. The woods are species of pines, beech, sweet gum, oak, *Rubus* and elm, and in large part the staining takes place in the lumber piles after the trees have been sawn into boards, planks, etc.

NEW METHOD OF MOUNTING FUNGI

A NEW method of mounting culture-grown fungi for preservation in the herbarium is described in the July number (1906) of the *Journal of Mycology* by George G. Hedgcock and Perley Spaulding. Pure cultures on rather stiff agar supply the specimens, which are taken out in little blocks with a layer of agar adhering, dried on stiff cards, and then protected by pasting on perforated pieces of thick cardboard of the proper size, the specimens occupying the opening. These cards may be attached to herbarium sheets, and preserved in the usual way, or they may be kept for easy reference in the manner of library cards in ordinary card cases.

ELEMENTARY BOTANY OF FLOWERING PLANTS

PROFESSOR MAST has published in a booklet of 54 pages a series of "experiments" intended to cover the essentials as to the structure and physiology of flowering plants in an elementary course in high schools and colleges. Dr. Mast having had "unsatisfactory results in beginning the study of plants and animals with such forms as *Amoeba, Paramecium* and *Spirogyra,*" he prepared a set of directions for his students (in Hope College), beginning the work with the flowering plants, and taking up in succession, seeds, stems, roots, protoplasm, leaves, modified plant structures (tubers, tendrils, spines, aerial roots, etc.) and flowers. The subjects for these studies are well selected, and the directions are clear. For those who believe in beginning with the higher plants (which we do not) the book must prove helpful, as indeed it will be suggestive to those who prefer the more natural sequence from the simple structures to the more complex.

FOREST TREES OF NEW JERSEY

DR. B. D. HALSTED in a recent bulletin (No. 202) of the New Jersey Experiment Station publishes a useful annotated list of the forest trees of New Jersey. He enumerates 104 species, of which 98 are natives, the others being exotics which have become pretty well established. Of the native species 13 are conifers, leaving 85 broad-leaved species. The largest genus is *Quercus,* the oaks, with 16 species, followed by *Pinus* (pines), *Acer* (maples) and *Salix* (willows) with 6 each, *Populus* (poplars) with 5 native and 2 adventive. Of the ashes (*Fraxinus*) and hickories (*Hicoria*) there are 4 species each. It

is significant that the author entirely omitted all of the hawthorns (*Crataegus*), apparently regarding the task of disentangling them as quite hopeless. Localities are given, and many notes are quoted from various state reports. Twenty-five of the species are illustrated by cuts borrowed from Sargent's "Manual of the Trees of North America."

THE GENUS CRATAEGUS IN AMERICA

Under this title, in the August number of the *Journal of Botany,* Professor Sargent publishes an interesting statement in regard to the new species of *Crataegus* (hawthorns), in which he refers to the small number known to Torrey and Gray (about fourteen), and says that some years ago it was noticed that trees grown from seeds from different parts of the country differed from the recorded descriptions in certain particulars. From this came a careful study of the genus in several states, the result being that about "five hundred species" have been described in the last eight years. "It is not surprising," he says, "that botanists, looking at the genus through the eyes of Torrey and Gray, or reaching their conclusions from the study of the scanty and generally incomplete material found in herbaria, have regarded the makers of all these species with pity, and have tried to throw ridicule on this investigation and its results." We are assured, however, that to those persons who engage in a study of these plants in the field "the fact is soon apparent that the genus contains many very distinct forms, whether these are to be called species or not."

Following this is a discussion of the groups (20) into which the species naturally fall, with notes on their geographical distribution. The study of the genus, as every one knows who has done anything with the species, is beset by many difficulties. Flowering specimens must be collected in the spring and fruiting specimens in the autumn, and since in many cases the trees look much alike, they must be marked carefully in order to avoid mistakes. After this must come the test through cultivation, of which a beginning has been made. On the grounds of the Arnold Arboretum nearly twenty-five hundred lots of *Crataegus* seeds have been planted, so that comparisons may be made of the seedlings with the trees from which they were derived in order "to determine the value of the field-work which has been done in this genus."

That the end is not yet in the matter of new species is evident from this sentence: "In every township of half a dozen states it is more than probable that forms exist which differ from those that have already been described, and many years will be needed to elucidate the characters and distribution of the genus in this country."

PHILIPPINE BOTANY

In the *Philippine Journal of Science,* under its new management, whereby the botanical articles constitute a separate series, there have appeared three numbers, namely, those for January, April and June. These have included articles as follows: "The Comparative Ecology of the San Ramon *Polypodiaceae,*" by E. B. Copeland; "The *Cyperaceae* of the Philippines," by C. B. Clarke; "The Occurrence of *Antiaris* in the Philippines," by E. D. Merrill; "Philippine Myxogastres," by George Massee; "*Cibotium baranetz* and related Forms," by H. Christ; "Pteridophyta Halconenses," by E. B. Copeland; "Spiciligium filicum Philippinensium," by H. Christ; "The Philippine Species of *Dryopteris,*" by H. Christ; "Notes on Philippine Palms, I.," by O. Beccari; "Index to Philippine Botanical Literature," by E. D. Merrill. The last-named paper is mainly an index to *recent* literature, and is quite evidently supplementary to Tavera's "Biblioteca Filipina," published in 1903 by the Library of Congress.

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EXPEDITIONS OF THE BERLIN ETHNOGRAPHICAL MUSEUM

The Ethnographical Museum of Berlin is organizing a number of important expeditions. Dr. Czekanowsky is going to visit the region of the Victoria Nyanza for the purpose of investigating the pygmy tribes of that area,

the expenses of this expedition being largely defrayed by Duke Adolf of Mecklenburg. Dr. Ankermann, assistant director of the museum, is preparing for a visit to the northwestern part of the Cameroons. The museum possesses large collections from this district, which were obtained on one of the military expeditions against the natives of the interior; consequently little is known regarding the material. Scientific studies on the material and on related anthropological questions will be carried on by Dr. Ankermann. A third expedition, organized with the support of the secretary of the navy, is under the leadership of Dr. Stephan, who will be accompanied by Mr. Edgar Walden and Dr. Otto Schlaginhaufen, whose field of work will be German New Guinea, New Britain and New Ireland. This expedition will be accompanied by a photographer, Mr. Richard Schilling. Still another expedition is directed towards the investigation of Central America. This work will be in charge of Dr. Walter Lehmann, who expects to spend two years among the natives of Costa Rica and other Central American states. Two other expeditions of the museum have just come to a close—the one conducted by Dr. Theodor Preuss, who has spent two years among the Cora and Huichol Indians in northwestern Mexico; the other, by Professor Seler, who has just returned from a year's investigations in various parts of Mexico.

THE SAN DIEGO MARINE BIOLOGICAL LABORATORY

THE city authorities and citizens of San Diego, California, have recently shown their interest in the San Diego Marine Biological Station in a very substantial way. It became obvious some months ago that the La Jolla Park, already given by the city for the use of the station, containing, as it does, less than four acres, was too small to permit the carrying out of the larger plans of the benefactors of the station, Miss E. B. Scripps and Mr. E. W. Scripps. Through a peculiar circumstance in its history the city is a large land owner. A pueblo lot of about 160 acres, having a full half mile of ocean front, was found to afford the most favorable site for the station. Under its organic law the city can not give away any of its public lands; it can only sell them at public auction to the highest bidder. An ordinance was consequently passed by the common council providing for the sale of this piece of land, it being understood both by the city officials and the citizens that the sale was for the purpose of giving the Biological Association a chance to buy the land at a minimum price. No other bidder appeared at the auction, and the association thus secured for $1,000 an unconditioned title to a tract of land with a present market value many times what was paid for it.

The *Alexander Agassiz,* the new boat of the San Diego Marine Biological Association, was recently launched from the Jensen yards in San Diego. The craft was designed expressly for the work of the station. She is an auxiliary, "ketch-rigged," center-board boat, with twin propellers driven by gasoline engines of 25 horse power each. Her length is 75 feet over all. She is broad, 20-foot beam, and low. Without centerboard her draft is four feet. She is expected to dredge and trawl to a depth of 1,000 fathoms, at least.

SCIENTIFIC NOTES AND NEWS

BY the act of the last legislature, the professor of geology at the State University of Colorado became also, by virtue of his office, the state geologist. $5,000 is appropriated annually for this service. Professor Russell D. George, the new state geologist, is making his survey this summer, accompanied by Ralph D. Crawford, the instructor of the department, in the Poudre Valley region and in Routt County.

EDWIN G. DEXTER, A.M. (Brown, '92), Ph.D. (Columbia, '99), since 1900 professor of education in the University of Illinois, and since 1905 director of the School of Education, has been appointed commissioner of education in Porto Rico, to fill the vacancy caused by the resignation of Dr. Roland P. Falkener.

PROFESSOR WILHELM STUMPF, the psychologist, has been elected rector of the University of Berlin.

Dr. Henry H. Rusby, dean of the New York College of Pharmacy, Columbia University, has been appointed official expert in drug products for the U. S. government.

Dr. T. F. Holgate, professor of mathematics and dean of the College of Liberal Arts of Northwestern University, has been granted a year's leave of absence, and Dr. U. S. Grant, professor of geology, has been appointed acting dean for one year. Dean Holgate sailed for Glasgow on September 5 and expects to spend most of the year at Cambridge.

Professor David P. Todd, in charge of the Lowell Expedition to the Andes, left Alianza in northern Chile on August 3, taking with him the 18-inch Amherst telescope to remount at a higher station in the Andes, near Lima, Peru. Mr. A. G. Ilse, chief mechanician of Alvan Clark & Sons, and Mr. Earl C. Slipher, of the Lowell Observatory, form part of the expedition, which has secured at the Alianza station photographs of the annular eclipse of July 10, drawings and photographs of the ringless phase of Saturn, and over 5,000 photographs of Mars, symmetrically placed at the late opposition, exhibiting every part of the planet's surface, and many of them showing clearly the much-disputed double canals.

Dr. N. L. Britton, director of the New York Botanical Garden, and Mrs. Britton, are now engaged in botanical explorations in Jamaica.

Professor J. Behrens, of the Experimental Station at Augustenburg, Baden, has been appointed director of the Biological Institute for Agriculture and Forestry at Dahlem, near Berlin.

Mr. Roe E. Remington, A.B. (Colorado, 1905), instructor in chemistry in the Iowa State University, has become chemist in charge of the fertilizing department of Armour and Co., Chicago.

The officers of the Esperanto Scientific Association, which met in connection with the recent Esperanto Congress at the University of Cambridge, are as follows: Professor Adolphe Schmidt, head of the Meteorological Observatory at Potsdam, as president; Professor J. J. Thomson, who holds the chair of experimental physics at Cambridge; and M. René Benoît, director of the International Office of Weights and Measures in Paris, as vice-presidents; and Professor René de Saussure (Geneva), as general secretary.

A monument to Mendeléef, the great Russian chemist, is to be erected by subscription on the grounds before the University of St. Petersburg.

The Place du Collège de France will, by decision of the Paris Municipal Council, hereafter be known as the Place Marcellin Berthelot.

Dr. Oren Root, professor of mathematics in Hamilton College, died on August 26, at the age of sixty-nine years. He succeeded his father as professor of mathematics at Hamilton in 1881.

Mr. Samuel Henshaw, who served for some years as head gardener of the New York Botanical Garden, died on Staten Island on July 16.

Professor Karl Vogel, director of the Astrophysical Observatory at Potsdam, died on August 13.

Dr. K. S. Storch, professor of chemistry in the Veterinary School of Vienna, died on July 22, at the age of fifty-five years.

We regret also to see announcements of the death of Dr. John Kerr, F.R.S., formerly professor of mathematics in the Glasgow Free Church Training College, and of Sir William Robertson Copeland, a Glasgow engineer, who had made a special study of drainage and water supply.

The U. S. Civil Service Commission invites attention to the examination scheduled to be held on September 11, 1907, for the position of acting assistant surgeon in the Public Health and Marine Hospital Service.

The emperor of China has established a zoological garden in the Imperial Gardens at Pekin, and animals, said to be of the value of $2,000,000, have been purchased by the Chinese minister at Berlin.

THE seventh International Physiological Congress met in Heidelberg last month, with Professor Kossel as president. *Nature* states that about 300 members were present, and 200 communications were made in the four sections into which the congress was divided. At the opening meeting Professor Kronecker paid a tribute to the late Sir Michael Foster. Professor Dastre, of Paris, gave a short biography of the late Sir J. Burdon-Sanderson, while Professor Sherrington spoke of the loss sustained by the congress through the deaths of Professor Errera, of Brussels, and Professor A. Herzen, of Lausanne. By order of Grand Duke Friedrich of Baden each member of the congress was given a bronze medal in memory of the meeting.

THE Vienna correspondent of *The British Medical Journal* states that a magnificent building has just been completed which will serve as part of the new institutes devoted to the researches required by the extension of modern science. At a distance of a few minutes' walk from the general hospital, a four-floor building with three large fronts has been erected. Therein will be situated the hygienic institute, with Professor Schattenfroh's lecture hall, the institute for the history of pathology with a large museum, the serum therapeutic institute (under Professor Paltauf), and the institute for examination of foodstuffs. In the center block are two large lecture halls, each accommodating 250 students. In the courtyards and also on the top floors, and under the roofs of the house, stables for the animals used for experiments have been erected. The arrangements are the result of very extensive studies of similar institutions made during the last five years. The cost amounts to upwards of $750,000. During this autumn and winter only a few of the buildings will be used, but next spring all the institutes will be ready for use and they will then be formally opened.

The British Medical Journal states that the French Congress of Medicine will be held in Paris under the presidency of Professor Debove. The opening meeting will take place on October 14, and will be continued on the 15th and 16th. Reports will be presented by MM. Linossier and Castaigne on the treatment of simple ulcer of the stomach; by MM. Gilbert Ballet and Delhelm and M. Sainton on the pathogeny and treatment of exophthalmic goitre; and by MM. Carrière and Marcel Labbé on hæmophilia. Among the subjects proposed for discussion are the surgical treatment of simple ulcer of the stomach; is pulmonary tuberculosis of aerial or intestinal origin? acid-resistant bacilli; the therapeutic action of radium; ionic medication; the use of collargol; the therapeutic value of tuberculin; the serumtherapy of dysentery and cutaneous sporotrichoses.

WE learn from the same journal that an Italian Medico-Legal Society has lately been founded. Its headquarters are in Rome. Professor Lombroso is honorary president, the actual president being Professor S. Ottolenghi. The aims of the society are the development of "a true and healthy medico-social conscience," the furtherance of scientific researches on medico-legal subjects, and the enlightenment of public opinion on such questions. The first problem with which the society proposes to grapple is the necessity of establishing intermediate institutions for the reception of offenders who can neither be imprisoned nor admitted into a lunatic asylum.

IN the Scottish National Exhibition to be held in Edinburgh in 1908 there will be, says *Nature,* sections devoted to fine arts, education and history, arts and crafts, mining, engineering and metallurgy, transportation and motive power, shipbuilding and waterways construction, chemistry and scientific appliances, lighting, heating and ventilation, agriculture, horticulture and sylviculture, domestic economy, sports and pastimes, botany and zoology, artisans' work, women's section, urban and rural improvements.

UNIVERSITY AND EDUCATIONAL NEWS

THE Massachusetts Agricultural College will celebrate the fortieth anniversary of its opening from October 2 to 5. The speakers in-

clude Dr. A. C. True, director of the Division of Experiment Stations, Department of Agriculture; Dr. Carroll D. Wright, president of Clark College; and Dr. F. W. Rane, state forester of Massachusetts.

THE permanent advisory committee of the treasury on the allocation of the money provided by parliament in aid of university colleges in Great Britain recommends grants as follows:

	Grant, 1906-7	Proposed Grant
Victoria University of Manchester	£12,000	£10,000
University of Liverpool	10,000	10,000
University College, London	10,000	10,000
University of Birmingham	9,000	9,000
University of Leeds	8,000	8,000
King's College, London	7,800	7,800
Armstrong College, Newcastle-on-Tyne	6,000	6,000
University College, Nottingham	5,800	5,000
University of Sheffield	4,600	5,000
Bedford College for Women, London	4,000	4,000
University College, Bristol	4,000	4,000
University College, Reading	3,400	3,400
Hartley University College, Southampton	3,400	2,250
London School of Economics		500

The grants proposed above amount in all to £84,950, leaving, if a grant of £1,000 to University College, Dundee, is continued, a balance of £14,050 available for grants for special purposes.

THE Philip Walker studentship of pathology at Oxford will be filled in October. The studentship was founded "for the furtherance of original research in pathology." It is of the annual value of £200 (payable quarterly in advance), and is tenable for three years. The student may be of either sex, and need not necessarily be a member of the University of Oxford.

PROFESSOR WILLIAM L. BRAY, of the University of Texas, has been appointed to the chair of botany at Syracuse University, vacant by the resignation of Professor J. E. Kirkwood.

DR. OLIVER C. LESTER, A.B. (Central College, Mo., 1897), Ph.D. (Yale, 1904), instructor in the Sheffield Scientific School of Yale University, has been appointed professor of physics in the University of Colorado, to fill the position vacant by the resignation of Professor Duane, who, as already announced, goes to the Curie Radium Laboratory of the University of Paris.

FRANK EUGENE THOMPSON, instructor in education at Stanford University, with leave of absence to carry on research work at Columbia University, has been appointed professor of education in the University of Colorado.

PROFESSOR GEORGE W. BISSELL, M.E. (Cornell, '88), professor of mechanical engineering in the Ohio State College since 1892 and vice-dean of engineering since 1904, has been appointed dean of engineering in the Michigan Agricultural College.

HOWARD C. FORD, instructor in civil engineering in the University of Colorado, has been appointed assistant professor of irrigation engineering at the Iowa State University.

MR. THOMAS D. EASON, graduate of the Clemson Agricultural College, has accepted an appointment as assistant in botany in the North Carolina Agricultural College.

DR. FRANK W. REED, of the University of Virginia, has been appointed instructor of astronomy in the University of Illinois.

DR. W. A. WILKINS has retired from the chair of pathology in McGill University.

DR. FRIEDRICH BERWERTH has been promoted to a professorship of petrography a the University of Vienna.

AT the University of Lille, M. Clairin has been appointed professor of mathematics; M. Mallaquin, professor of zoology, and M. Hallez, professor of comparative anatomy; at the University of Nancy, M. Minguin has been appointed professor of chemistry and M. Nicklès professor of geology; at the University of Lyon, M. Vavasseur has been appointed professor of the differential and integral calculus; at the University of Toulouse, M. Paraf has been appointed professor of mathematics; at the University of Poitiers, M. Turpain has been appointed professor of physics.